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Optimization of sweetener blends for the preparation of Indian ethnic snack

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Abstract: **Sweets are prepared with the high amount of sucrose, which not good for dietetic consumers. Sucrose was successfully replaced with the sweetener blends for the preparation of the indigenous cereals snack (*Shankarpoli)*. The study was conducted with artificial sweetener blends based sweetening agents to be used in the preparation of Indian snack i.e. *Shankarpoli*. Various sweeteners stevia, maltitol and sucralose blends were used in the preparation of snack. Several possibilities exist to exploit the benefits of artificial sweeteners in the bakery and confectionery processing plant to enhance the safety from disease related to high-calorie intake and quality of products. The threshold intensity for sugar, stevia, maltitol, and sucralose were 0.5, 0.027, 1.8 and 0.005 g respectively. *Shankarpoli* was prepared using refined wheat flour. In *Shankarpoli* sugar and sweetener blends were added by sprinkle method because sprinkle process enhances the texture of snack compared with other processes. The sensory evaluation of snacks was done by Qualitative Descriptive analysis (QDA) and there was no significant difference in typical attributes of the snack, but the overall acceptance was found higher in blend 8 (8g maltitol, 0.0775g stevia, and 0.00775g sucralose) with minimum lingering sweetness.**

Keywords: **Shankarpoli, Sucralose, Stevia, Maltitol, Qualitative Descriptive analysis.**

1. INTRODUCTION

Shankarpoli is an indigenous snack of India. The product is popular in the southern and western part of India. It contains refined wheat flour and sugar. The dietary options of replacing sugar with artificial sweetener could be especially helpful in management of ailments like obesity and diabetes mellitus, which have become an epidemic worldwide nowadays. According to report of World Health Organization, India has a in doubt distinction of being the diabetic country of the world with over 32 million people affected by it, whereas the figure is close to 171 million for rest of the world and expected to touch 366 million by 2030 [1]. Artificial sweetener like stevia, maltitol and sucralose can be used for sugar replacement. Maltitol is a noncaloric, nonglycemic and noncariogenic polyol with a high digestive tolerance. Stevia is natural high-intensity sweeteners and the extracted from the leaves of the plant Stevia rebaudiana. They are having noncaloric, nonglycemic and noncariogenic properties. Stevia has a sweetness of up to 300 times greater than sucrose [2, 3]. Sucralose is an artificial sweetener with a sweetness ranging from 500 to 750 times greater than the sucrose reference samples and a clean sucrose like sweetness [4].

Currently, consumers are expecting to add delight from food and want that these foods contain good sensory qualities; consequently, industrialists are constantly working to improve the sensory superiority of foods to response for consumer's expectations [5]. Additionally, consumers want to use such products those have the low amount of sugar and calories, and which can control or maintain their wellbeing and health. Neither bulk nor high-intensity sweeteners can provide a quality and optimal sweet taste alone. Distasteful flavors, aftertastes and mouth feel are often sensed and obstruct one-to-one sugar substitution. Several industries frequently use sweetener blends to beat the sensory limitations of individual sweeteners [6]. The synergism of sweetener blends of sweeteners makes probable reduction in their individual amounts, making them safe for use and more pleasing than the sole one. These blends, in different level, can permit the enhancement of textural and sensorial characteristics of a food product [7]. These blends of sweeteners may enhance the stability, quality, sweetening power, and to reduce expenses and also to increase the choices for the consumer for low calorie products [8]. For optimization response surface methodology (RSM) is an important tool for improvement in product quality [9]. It is a group of statistical measures that is use to explore the relationships between dependent variables and independent variables [10].

Therefore, the objective of the current investigation was to optimize Indian traditional snack *shankarpoli* acceptability with regards to proportions of sweeteners maltitol/stevia/sucralose blends, using response surface methodology to obtain the product with the most possible sensory appealing and improve textural characteristics.

2. MATERIALS AND METHODS

Materials:

Maltitol and sucralose (food grade) were procured from the laboratory of CFTRI, Mysore, India and food grade stevia was procured from Stevia World Agrotech Pvt, Ltd. Bangalore, India. Refined wheat flour, palm oil and other ingredient purchased from local market.

Sample preparation:

Took 100g of refined wheat flour to which add a pinch of salt and hot refined oil (20ml) and mix properly to form a dough using 50 ml of water. Then the dough was rolled into two layer sheets of 1.5-2.0 mm thickness and cut it into a diamond shape and deep fried into hot (165^{0}C-170^{0}C) till golden brown color. Take out from oil and sprinkle the sweetening agent either sugar or blend of sweeteners at hot condition [11]. While traditionally sugar was being mixed during the dough preparation that decreases the crunchiness of the snack.

Texture analysis:

Shankarpoli sprinkled with Sugar and sugar substitutes were used for analyzing shearing strength using the texture analyzer (model TA-HDi Texture Analyzer, Stable Micro Systems, Surrey, UK). Samples used were of 7 cm length and 1 cm thickness. The test was carried out under the following conditions: load cell-50 kg, crosshead speed 10mm/min [11]. The average of three replicates was reported in Newton (N).

Psychometric study:

Selection of panelists:

A group of 10 trained panelists was selected from the scientific staff of the Traditional foods and Sensory Science Department, CFTRI Mysore, India for psychometric tests threshold and Quantitative Descriptive Analysis (QDA). Sensory evaluation was carried out in the sensory booth room built according to ASTM standard [12].

Threshold study:

The threshold value is the minimum concentration of a substance which when present in plain water is detectable or we can say it differs from plain water. Threshold test for the sugar and intense sweeteners were conducted as per the method IS: 5126 [13]. The stock solution was prepared for sucrose is 10%, for maltitol 15%, and for stevia 0.5% .25% of sucralose. From these stock solutions, a series of dilution was made the increasing concentration of sweetness. Generally, geometric series was prepared for deciding the concentration of arithmetic series. This arithmetic series ranged from 0.1 to .6% for sugar was prepared and tested by trained panelists. The series for other intense sweeteners were maltitol (0.15 - .9%) stevia (0.005 -0.03%) and sucralose (0.0025-0.0125%). All these samples of dilutions have different intensity of sweetness. Then samples were presented to the panelists and they were asked to taste the samples arranged in increasing order in terms of concentration of sweetness and mark ‘0’ when no stimulus is found, ‘?when the stimulus was perceived to be different from blank but not recognizable and ’X’ for Threshold value, i.e., the lowest concentration at which the panel could perceive and recognize the sweetness [11].

Sensory evaluation:

Sensory evaluation was carried out in the sensory booth room built according to ASTM standard [12]. The selected panel consisted of 10 judges from Sensory Science Department who regularly participated in sensory analysis studies and had experience in profiling food products were selected as sensory panel members. QDA was selected for the sensory analysis as it gives full information of sensory attributes [14]. The scorecard consisted of a 15 cm scale in which 1.25 cm was anchored as low i.e. recognition threshold and saturation threshold at 13.75 cm [11].

Statistical analysis and Experimental design:

All experiments were conducted in triplicate and the mean was used for further interpretation of results. The data were subjected to one way analysis of variance (ANOVA) using statistical software SPSS for identifying attributes causing effect among the samples. The mean scores of three replicates were calculated and sensory profilogram was drawn. For optimization design response surface methodology, Design-Expert version 7.0.0 Stat-Ease, USA was used.

Central composite design:

The central composite rotatable design (CCRD) was used for design the experiments. Twenty experiments were carried out according to optimization design with 3 factors 5 levels for each variable. Five levels of variables were applied to study the responses viz. sweetness, lingering sweetness and overall acceptability (OAA) on QDA scale. A rotatable central composite design was applied to optimize the amount of sweeteners for sprinkling on *Shankarpoli* given in Table 3). Maltitol (X_1), stevia (X_2) and sucralose (X_3) were used as an independent variable and the levels of these sweeteners were selected on the basis of laboratory trials (Table 3). The effect of these independent variables on sweetness, lingering sweetness and overall acceptability of the product were investigated using CCRD.

$$Y_k = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{13} x_1 x_3 \quad \text{(Eq.1)}$$

The predicted values were obtained from the above regression equation and coefficient of determination (R^2), standard error analyzed. Analysis of the coefficients of regression models was carried out by ANOVA to identify the significance of each coefficient. The lack of fit was also intended. Response surface plots were developed by second-order polynomial models for responses viz. sweetness, lingering sweetness and OAA keeping the two processing variables at the centre point (Table 2). Various constraints were set for independent and dependent variables along with their relative importance (Table 6). Optimization of the fitted polynomials was done using a desirability function [15]. The optimum condition was confirmed by conducting experiments at predicted values of variables; responses were monitored and results were compared with a model of predictions [16].

3. RESULTS

Threshold test:

The threshold values were found for sugar, stevia, maltitol, and sucralose were 0.5, 0.027, 1.8 and 0.005 g respectively. This test was done to know the minimum concentration of sweetener that can show any changes in the water. This was a basis for the preparation of blend. As stevia has a bitter taste, so it is important to decide the minimum level of recognition.

Texture analysis:

The texture analysis of *Shankarpoli* with control (sucrose) and other sugar substitutes was analyzed using a texture analyzer (Fig. 1). The peak force (N) did not differ between the samples significantly ($p \leq 0.05$), and it ranged from 6.5 to 8.0 N. The texture analysis of *Shankarpoli* with control (sucrose) and other sugar substitutes was analyzed using a texture analyzer (Fig. 1). The peak force (N) did not differ between the samples significantly ($p \leq 0.05$). Patil, et al., [11] also found similar results *Shankarpoli* sprinkled with sugar and sugar substitutes.

Sensory profile of *Shankarpoli:*

The sensory profile of *Shankarpoli* was prepared with different syrup blend of sweeteners was shown in Fig.2 The samples were analyzed for sensory quality in terms of color; sweetness; texture; i.e. puffiness, grittiness, sweeteners coating lingering sweetness, and crispiness, fried oil and overall quality. All the above-optimized blend of sweeteners were sprinkled on the product and evaluated for sensory analysis. There was no significant difference in the color, puffiness, sweetener coating, grittiness, crispiness and cereal like the taste of the product**.** All samples had well sensory attributes but blend 8 was found highest overall acceptability among all the samples.

Patil, et al., [11] worked on the development of low-calorie snack food based on intense sweeteners and found that in the sensory evolution of *Shankarpoli* prepared by using refined wheat flour was no significant difference in typical attributes of the snack. They analyzed that aspartame and acesulfame-K had the same sweetness intensity were as sucralose had a higher intensity of sweetness.

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Optimization:

The effect of maltitol, stevia, and sucralose on sweetness, lingering sweetness and overall acceptability of *Shankarpoli* are shown in Table 3.

Analysis of Fitted Model and Surface Plots for

***Shankarpoli's* Sweetness**

The model F-value of 33.61 implies that the second order model for sweetness is significant at 5% level of significance (Table 4). The value of R^2 is 96.80% indicates that 3.2% of the total variation was not explained by the model. The value of the adjusted determination coefficient (Adjusted R^2 = 93.92%) was high to support a high significance of the model which indicates that second order terms were sufficient and higher order terms were not necessary. The magnitude of p-value (Table 5) indicates that linear terms of all variable have a significant effect at 5% level of significance ($p < 0.05$) on the sweetness of the product. Further quadratic effect of stevia and interaction between maltitol: stevia; maltitol: sucralose; stevia: sucralose and all the linear terms have a significant effect at 5 % level of significance ($p<0.05$). The equation of the model fitted for the sweetness of *Shankarpoli* in the actual form of process variables after eliminating the non-significant terms is

$$Y_1= 2.34+0.14X_1+0.064X_2+0.068X_3+0.019X_1X_2+0.016X_1X_3+0.009X_2X_3-0.067X_1^2+0.007X_2^2-0.002X_3^2. \quad \text{(Eq.3)}$$

The magnitude of β revealed that the linear term of all the sweeteners have a positive effect which indicates that with increase sweetener content, there will be an increase in sweetness, whereas quadratic term of maltitol content has the maximum negative effect (β= -0.067) followed by sucralose (β = -0.002). The effects of maltitol (X1), stevia (X2), and sucralose (X3) on the sweetness of the *Shankarpoli* are represented by the response surface plots (Fig. 3a-c). Similar results were found by Naik and Londhe [17] that aspartame, sorbitol, and maltodextrin effects significantly. Their synergistic effects have also been seen in the preparation of kulfi.

Lingering sweetness of *Shankarpoli:*

The regression equation for the lingering sweetness of *Shankarpoli* was determined in terms of coded variables as Eq.4. An ANOVA result for quadratic models of lingering sweetness is given in Table 5. The model F-value of 8.68 implies that the second order model for sweetness is significant at 5% level of significance (Table 4). The value of R^2 is 88.65% indicates that 11.35% of the total variation was not explained by the model. The value of the adjusted determination coefficient (Adjusted R^2 = 78.44%) was high to support a high significance of the model which indicates that second order terms were sufficient and higher order terms were not necessary. ANOVA also shows that there was a non-significant lack of fit which further validates the model. The 3D response plot is the graphical representation of the regression equations from where the values of responses can be predicted with respect to the variable factors (Fig. 4 a-c). The equation of the model fitted for lingering sweetness is

$$Y_2=1.21-0.032X_1+0.065X_2+0.022X_3+0.0021X_1X_2-0.0021X_1X_3+0.0133X_2X_3+0.014X_1^2+0.037X_2^2+0.021X_3^2. \quad \text{(Eq.4)}$$

The magnitude of p-value (Table 5) indicates that linear terms of all variable have significant effect at 5% level of significance ($p < 0.05$) on sweetness of the product. Patil et al., [11] had reported that the lingering sweetness in the final products was higher in sugar substitutes as compare to sucrose.

Overall acceptability of *Shankarpoli:*

The effects of maltitol (X1), stevia (X2), and sucralose (X3) on the sweetness of the *Shankarpoli* are represented by the response surface plots (Fig. 5 a-c). Sensory evaluation helps to define the product characteristics which are very important with respect to customer acceptance of the product [18]. From the response surfaces and contour plots, it is clear that the overall acceptability value increased with increase in maltitol and decreased with stevia and sucralose. The ANOVA data showed that the model is significant and lack of fit is no significant (Table 4). The high values of coefficient of determination (R^2= 96.85) and adjusted R^2 of 94.01 also showed that the model is highly significant and showed only 5.99% of the total variation was not explained by the model. Response surface and contour plot showed that up to a certain limit acceptability increased as the independent variable interacted with each other. The overall acceptability was highest at maltitol 8g, stevia 0.0775g, and 0.00775g sucralose content. The combination of medium levels of all factors resulted in the highest scores in terms of overall acceptability. The equation of the model fitted for overall acceptability is

$$Y_3=2.74+0.12X_1+0.056X_2+0.059X_3+0.018X_1X_2+0.013X_1X_3+0.0083X_2X_3-0.057X_1^2+0.0054X_2^2-0.0021X_3^2. \quad \text{(Eq.5)}$$

The magnitude of β coefficients revealed that the quadratic term of maltitol have the maximum negative effect (β = -0.057) followed by sucralose (β = -0.0021) whereas stevia content has a positive effect (β = 0.054) on snack overall acceptability (Table 5). Melo et al., [8] reported the importance of the synergistic effect of blend of aspartame:acesulfame-K on reduction of cost and healthier as compared to when used separately. According to Yang et al., [19] rebaudioside A, erythritol, and isomalto-oligosacáridos appreciably influences the sensory attributes, hardness, viscosity, and consistency of yoghurt which supports to the present study.

Optimization of *Shankarpoli* Formulation:

Optimization of *Shankarpoli* formulation was based on maximum sweetness, overall acceptability and minimum lingering sweetness to achieve the low-calorie product that is comparable to placebo. In order to optimize the formulation for preparation of low-calorie sugar-free snack *Shankarpoli* by numerical optimization technique, equal importance was given to all the three parameters viz. maltitol, stevia and sucralose content (Table 6). The optimum concentration was determined by superimposing the contour plots of all the responses and finding the region where the amount of sweeteners were 'near' optimal for all the responses [15, 16]. The optimum solution obtained by optimization score was sweetness 5.70, lingering sweetness 1.39, and overall acceptability 7.69, respectively (predicted values) and desirability for this formulation was 0.841. This set of concentration was determined to be optimum by the RSM optimization approach and was used to validate experimentally. The experimental values, mean of three trials (Table 7) were found to be in close agreement with the predicted values and were within the acceptable limits showed the adequacy of selected models.

4. CONCLUSIONS

RSM was successfully applied to assess and model effects of three levels of three ingredients (maltitol, stevia, and sucralose) on the overall acceptability of the product. For the optimization of sweeteners used for sprinkling on *Shankarpoli* response surface methodology was found to the best tool. Thus *Shankarpoli* can be prepared without sugar keeping desirable quality par requirement and better texture and mouthfeel with less amount of calorie intake.

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APPENDIX- I

Table 1: Optimization table for the Preparation of sprinkler

Runs	**Maltitol (g)**	**Stevia (g)**	**Sucralose (g)**
Blend 1	4	0.0325	0.00325
Blend 2	8	0.0325	0.00325
Blend 3	4	0.0775	0.00325
Blend 4	8	0.0775	0.00325
Blend 5	4	0.0325	0.00775
Blend 6	8	0.0325	0.00775
Blend 7	4	0.0775	0.00775
Blend 8	8	0.0775	0.00775
Blend 9	3	0.0550	0.00550
Blend 10	9	0.0550	0.00550
Blend 11	6	0.0172	0.00550
Blend 12	6	0.0928	0.00550
Blend 13	6	0.0550	0.00172
Blend 14	6	0.0550	0.00928
Blend 15	6	0.0550	0.00550
Blend 16	6	0.0550	0.00550
Blend 17	6	0.0550	0.00550
Blend 18	6	0.0550	0.00550
Blend 19	6	0.0550	0.00550
Blend 20	6	0.0550	0.00550

Table 2: Coded and decoded levels of independent variables used in the RSM design

Independent variables	Symbols	-1.682	-1	0	1	1.682
Maltitol	X_1	2.64	4	6	8	9.36
Stevia	X_2	0.0172	0.0325	0.055	0.0775	0.093
Sucralose	X_3	0.00172	0.00325	0.0055	0.00775	0.0093

Table 3: Central composite arrangement for independent variables X_1 (Maltitol, g), X_2 (Stevia, g), X_3 (Sucralose, g) and their responses (Sweetness, Lingering Sweetness, OAA).

Runs	Variables (Uncoded)			Responses		
	X_1(Maltitol)	X_2(Stevia)	X_3(Sucralose)	Sweetness	Lingering Sweetness	OAA
1	-1(4)	-1(0.0325)	-1(0.00325)	4.24	1.46	6.23
2	1(8)	-1(0.0325)	-1(0.00325)	5.32	1.4	7.31
3	-1(4)	1(0.0775)	-1(0.00325)	4.48	1.7	6.47
4	1(8)	1(0.0775)	-1(0.00325)	5.64	1.66	7.65
5	-1(4)	-1(0.0325)	1(0.00775)	4.75	1.58	6.75
6	1(8)	-1(0.0325)	1(0.00775)	5.87	1.5	7.86
7	-1(4)	1(0.0775)	1(0.00775)	4.86	1.98	6.88
8	1(8)	1(0.0775)	1(0.00775)	6.72	1.91	8.73
9	-1.68(2.64)	0(0.055)	0(0.0055)	3.66	1.79	5.65
10	1.68(9.36)	0(0.055)	0(0.0055)	5.73	1.3	7.72
11	0(6)	-1.68(0.0172)	0(0.0055)	4.84	1.42	6.83
12	0(6)	1.68(0.093)	0(0.0055)	6.38	2.01	8.38
13	0(6)	0(0.055)	-1.68(0.00172)	4.95	1.57	6.93
14	0(6)	0(0.055)	1.68(0.0093)	6.02	1.6	8.03
15	0(6)	0(0.055)	0(0.0055)	5.35	1.43	7.36
16	0(6)	0(0.055)	0(0.0055)	5.45	1.4	7.46
17	0(6)	0(0.055)	0(0.0055)	5.53	1.44	7.54
18	0(6)	0(0.055)	0(0.0055)	5.67	1.48	7.68
19	0(6)	0(0.055)	0(0.0055)	5.52	1.55	7.53
20	0(6)	0(0.055)	0(0.0055)	5.46	1.43	7.46

Table 4: Analysis of variance (ANOVA) data for the responses

Source of variations	Df	Sweetness		Lingering Sweetness		OAA	
		Mean square	F	Mean square	F	Mean square	F
Regression	9	0.052	33.61	0.012	8.68	0.038	34.11
Linear	3	0.395	254.82	0.078	58.22	0.29	259.09
Square	3	0.066	42.70	0.029	21.51	0.05	42.62
Interaction	3	0.006	3.59	0.001	1.11	0.004	4.02
Lack of Fit	5	0.0026	5.03	0.0022	4.62	0.0018	4.80
Pure error	5	0.0005		0.0005		0.0004	
Total	19	0.5221		0.1227		0.3842	
R2 (%)		96.80		88.65		96.85	
R2 (adj) (%)		93.92		78.44		94.01	

Table 5: Regression coefficients for second-order polynomial equation representing the relationship between the responses and process variables

	Sweetness		Lingering Sweetness		OAA	
	Coefficient	p value	Coefficient	p value	Coefficient	p value
Variables	2.34	< 0.0001	1.21	0.0011	2.74	< 0.0001
X_1	0.14	< 0.0001	-0.032	0.0099	0.120261	< 0.0001
X_2	0.064	0.0001	0.065	< 0.0001	0.055578	0.0001
X_3	0.068	< 0.0001	0.022	0.0468	0.059204	< 0.0001
X_1^2	-0.067	< 0.0001	0.014	0.1812	-0.05701	< 0.0001
X_2^2	0.007	0.5365	0.037	0.0033	0.00536	0.5550
X_3^2	-0.002	0.8697	0.021	0.0555	-0.00207	0.8182
$X_1 X_2$	0.019	0.1935	0.002	0.8746	0.017591	0.1662
$X_2 X_3$	0.016	0.2863	-0.002	0.8744	0.013403	0.2817
$X_1 X_3$	0.009	0.5509	0.013	0.3278	0.008275	0.4984

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Table 6: Constraints Set for the Optimization

Variables	Goal	Limits	Importance
Maltitol (g)	is in range	4.00-8.00	3
Stevia (g)	is in range	0.0325-0.0775	3
Sucralose (g)	is in range	0.00325-0.00775	3
Sweetness	is in range	3.61-6.76	3
Lingering sweetness	minimize	1.3-2.01	5
Overall acceptability (OAA)	Maximize	4.00-9.00	5

Table 7: Predicted and experimental values of responses for *Gulabjamun* using optimum process parameters

Values	Responses variables			Desirability
	***Gulabjamun* Juiciness**	**Lingering sweetness**	**OAA**	
Predicted	5.70	1.39	7.69	0.841
Experimented	5.75±0.15	1.34±0.05	8.16±0.06	

APPENDIX II

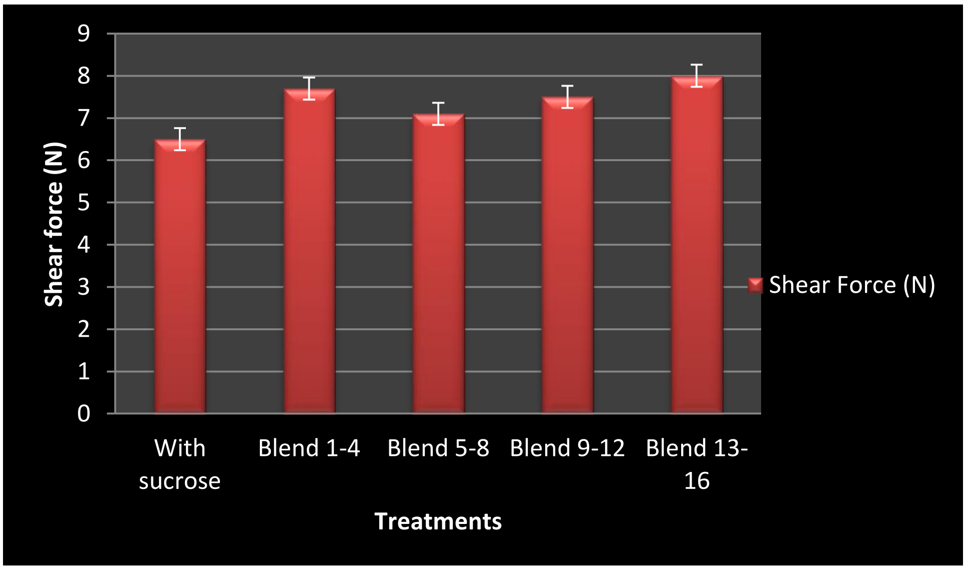

Fig 1: Texture analysis of samples

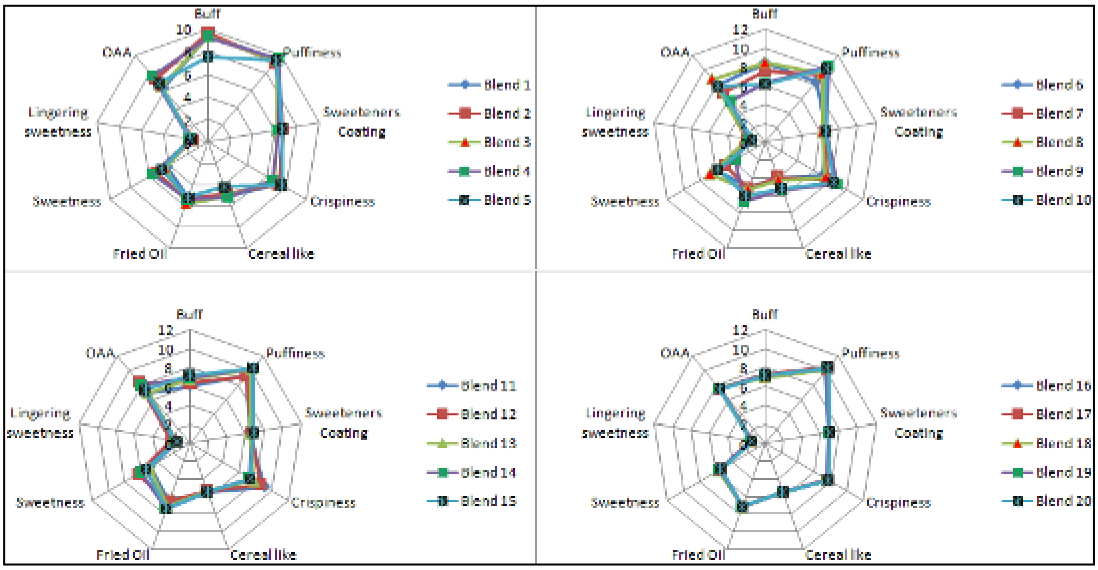

Fig 2: Sensory Profilogram of *shankarpoli*

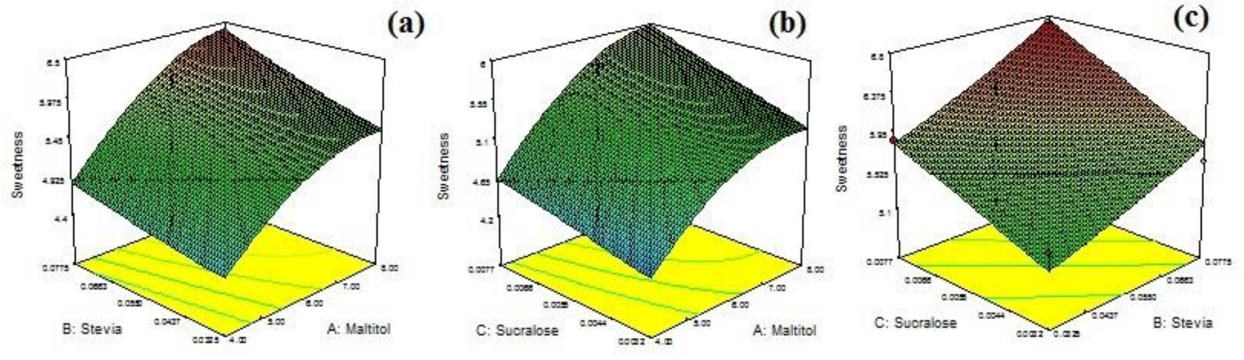

Fig 3: (a-c) Response Surfaces Plots showing interaction effect of variables sweetness of *Shankarpoli*

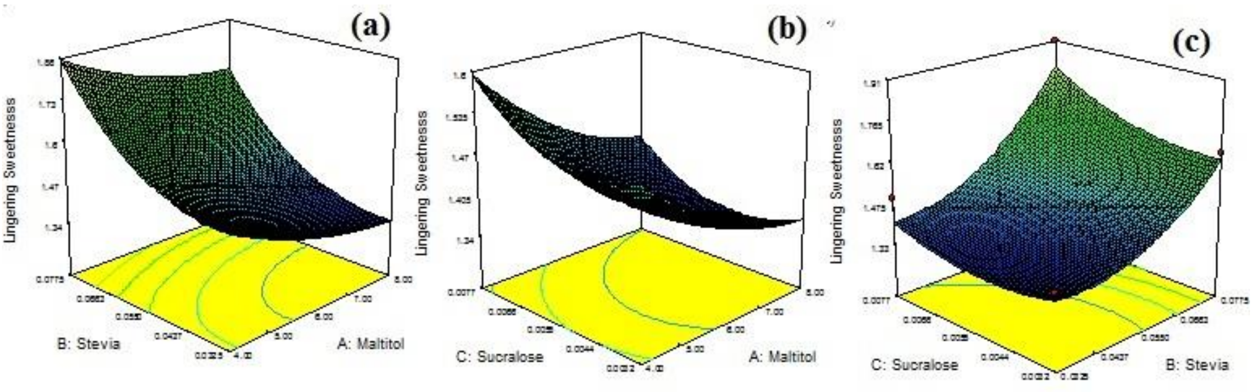

Fig 4: (a-c) Response Surfaces Plots showing interaction effect of variables Lingering sweetness of *Shankarpoli*

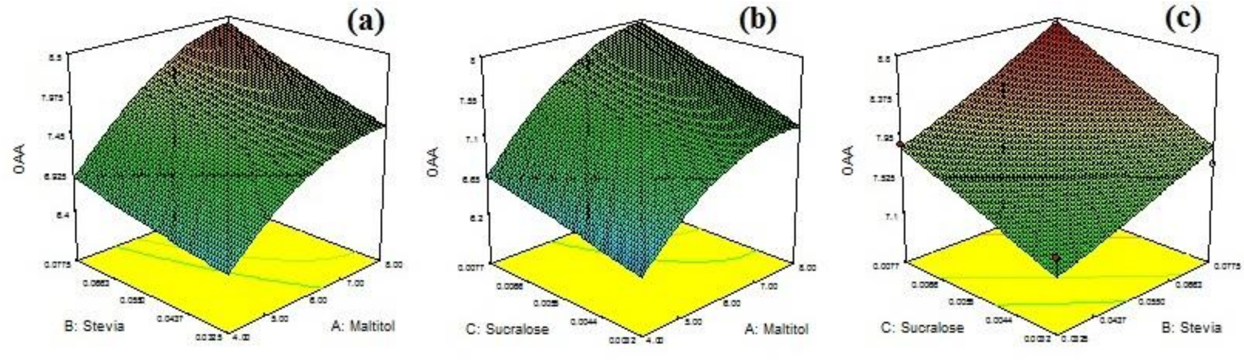

Fig 5: (a-c) Response Surfaces Plots showing interaction effect of variables overall acceptability of *Shankarpoli*